Detector Upgrade R&D Plans

RHIC Program Review
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T. Ludlam

BROOKHAVEN NATIONAL LABORATORY

Office of Science
U.S. DEPARTMENT OF ENERGY

The basis for a Detector Upgrade R&D plan…

1. RHIC has made a major discovery, and is now entering a New Era –
    - Exploring hot, dense, thermal matter
2. The basic configurations of PHENIX and STAR remain valid for the "Decadal" future.
    - Focus on hadrons, leptons, photons in central rapidity region.
    - Continued and improved capability for Spin measurements.
3. The new physics measurements require increased event rates and improved sensitivity to rare processes, including heavy quark states
    - Specific upgrades to PHENIX and STAR, plus Machine upgrades
4. Detector upgrades require…
    - Development of new (emerging) technologies
    - Advances in present technologies
    - Studies/tests to match detector performance to physics requirements
5. Plan for staged upgrades in a sequence driven by R&D requirements

The urgency of an R&D program... One example from the dawn of RHIC:

Projected Timescale for Integrated Circuit readout electronics

The Problem:

Huge number of readout channels…

Not feasible to store signals with delay cables.

Technology for analog pipelines existed, but major effort required to develop IC's for specific RHIC applications.

The Result:

R&D initiated in 1990 (3 years prior to completion of CDRs) at LBL, MIT, ORNL made it possible for RHIC detectors to employ next-generation readout electronics.

July, 1988 RHIC Workshop
working group: Bill Cleland et al.

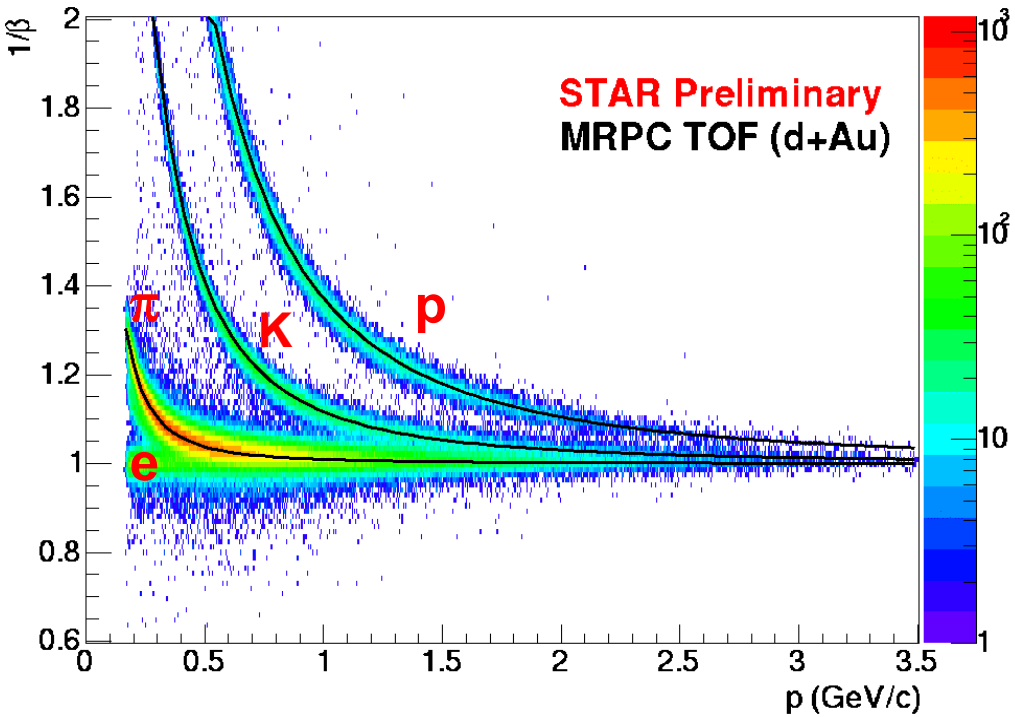
1989	Design Start
1990	First chip element prototypes
	Start system design
1991	Complete chip element prototyping
1992	System prototypes
	Full bench tests
1993	Early production units
	Test beam studies
	Design refinements
1994	Full production
	Installation into detector elements
	Calibration in test beams
1995	Detector systems tests
	Installation into full detector

Critical Role of R&D(1)…large-area Time of Flight

STAR Conceptual Design (1993) included a TOF array surrounding the TPC

- Not implemented: conventional Scintillator + PMT not practical (too costly)

- 1996 NSAC Subpanel Review: "Further R&D should be encouraged to search for a viable solution for large area coverage."



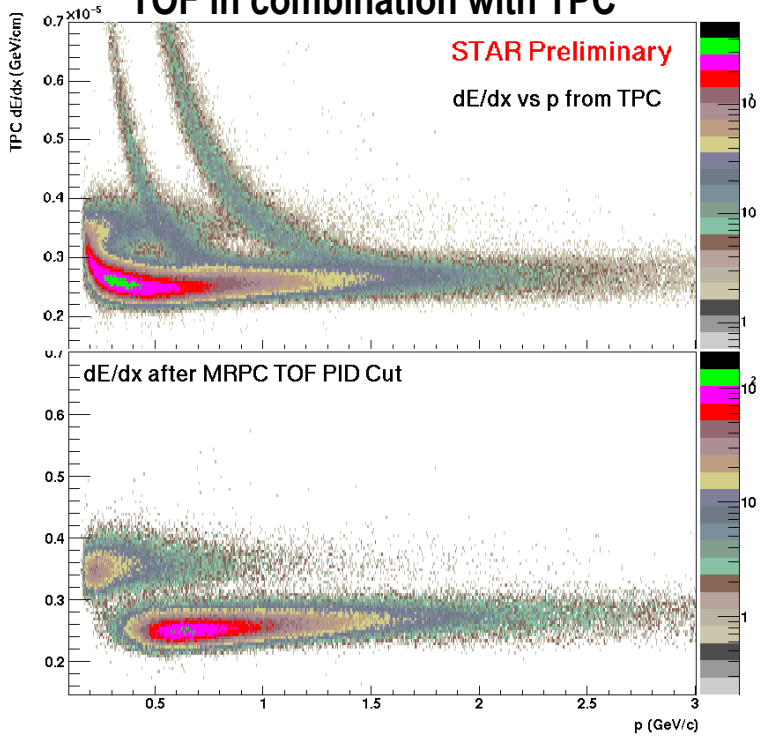
LHC/ALICE/STAR R&D –

Development of Multi-gap Resistive Plate Chamber as a practical technology for large detector systems, with <100 ps resolution for a few hundred $/ch. … building on the "Pestov" concept.

Multi-Gap Resistive Plate Chambers:
Cover large areas with affordable, high-resolution TOF

It is now practical for STAR to propose covering the entire outer barrel of the TPC with 24,000 time-of-flight channels with $\Delta t < 100$ps.

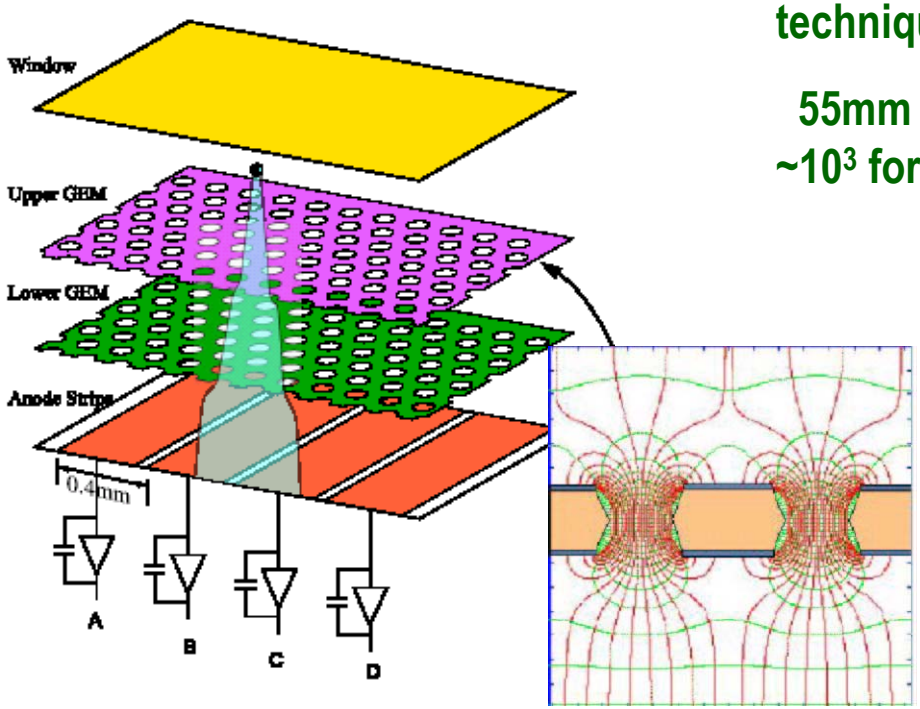
Added benefit: electron tag with TOF in combination with TPC



Critical Role of R&D(2)…New technology for tracking

Fine grain, High resolution, Compact Gas detector for high-rate TPC:

GEM = Gas Electron Multiplier



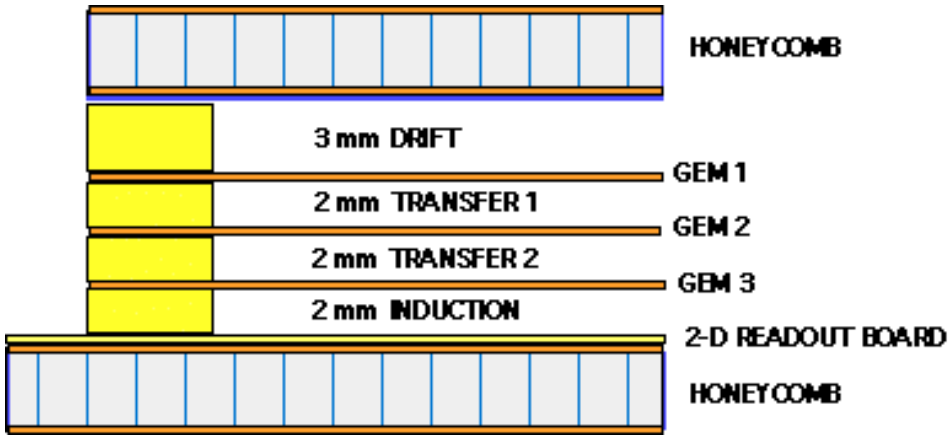
A micropattern structure produced in 50mm thick copper clad kapton using lithographic techniques.

55mm holes on ~140mm centers. Gain up to ~10^3 for single foil.

First development: CERN

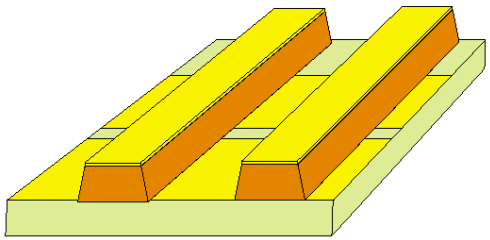
Development for RHIC:
- **BNL**
- **Weizmann Inst.**
- **Yale**

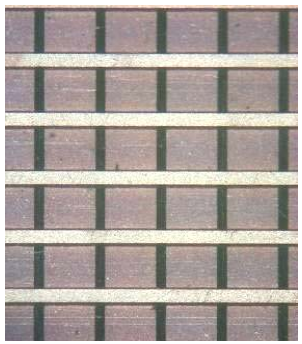
GEM technology used successfully in high intensity fixed target environment at CERN (COMPASS)



Triple GEM used with 0.4 mm pitch crossed strip readout to achieve

46 micron resolution in both coordinates.





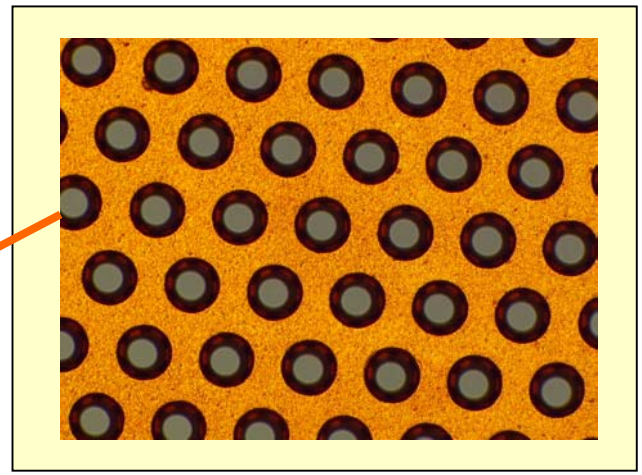
This is an excellent candidate for an inner tracker and Hadron Blind Detector in PHENIX, and a second-generation, high-rate Tracker for STAR.

PLAN: Joint PHENIX and STAR R&D to develop GEM technology for the RHIC environment.

New GEM Foils from 3M

3M Microinterconnect Systems Division, Austin, TX
In collaboration with Univ. Chicago (J.Collar)
hep-ex / 0304013 (April 2003)

Roll-to-roll process



50 micron holes on 140 micron centers.

45 foils (10x10 cm^2) received in June and are presently being tested at BNL and in Japan

Another challenge: high-density, low-noise, low-power readout electronics!

Critical Role of R&D (3)… Next generation Si tracker

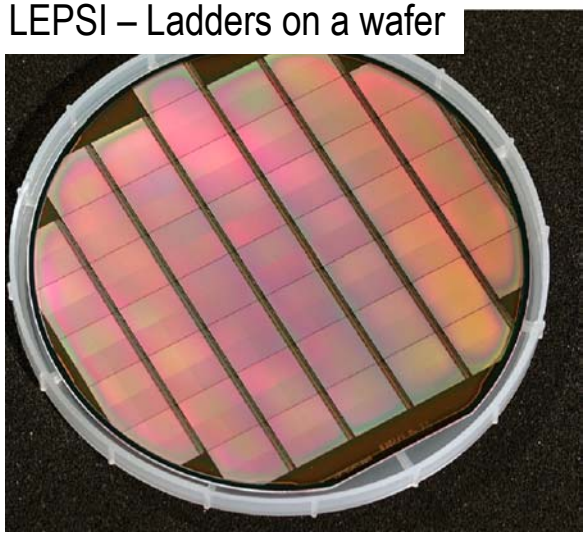
High resolution inner vertex detector based on current CMOS Active Pixel Sensor (APS) technology

Second generation silicon replacement

Required Areas of development:

- APS detector technology
- Mechanical support and cabling for thinned silicon
- Thin beam pipe development
- Calibration and position determination

LEPSI – Ladders on a wafer



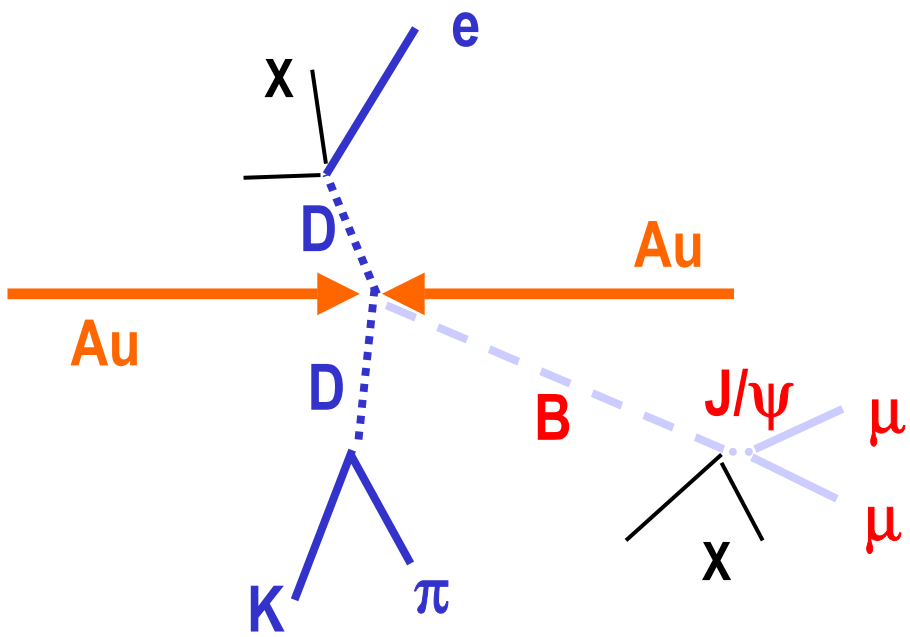
"[The R&D] proposed here may influence the future direction of development in the microvertex field at large"
RHIC Detector Advisory Comm.
Dec. 2002

Direct Observation of Open Charm and Beauty:

Y. Akiba (RIKEN; PHENIX)

Detection of decay vertex will allow a clean identifications of charm and bottom decays

	m GeV	cτ μm
D^0	1865	125
$D^{\pm}$	1869	317
B^0	5279	464
$B^{\pm}$	5279	496



Detection options:

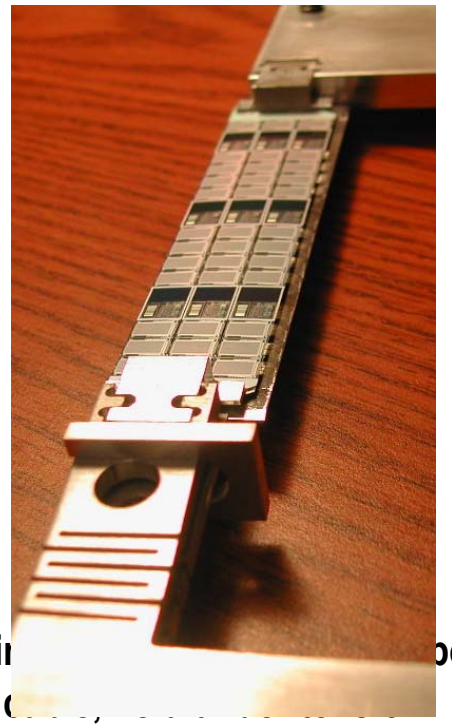
- Beauty and low p_T charm through displaced e and/or μ
- Beauty via displaced J/ψ
- High p_T charm through $D \rightarrow \pi K$

Need secondary vertex resolution < 50 μm

Beauty and high p_T charm will require high luminosity

APS Development H. Wieman (LBL; STAR)

- **Develop fast, low-power readout for current generation of APS**
  - All pixels read out; data reduction off detector
- **Develop second generation APS technology with on-chip zero suppression**
- **This technology has great potential for this application as well as for other future detectors**
  - Standard CMOS available through MOSIS
  - Allows on chip signal processing
  - Demonstrated radiation hardness better than CCDs
  - Considerable commercial interest advancing the technology
    - CMOS sensor unit sales to exceed CCDs by 2004



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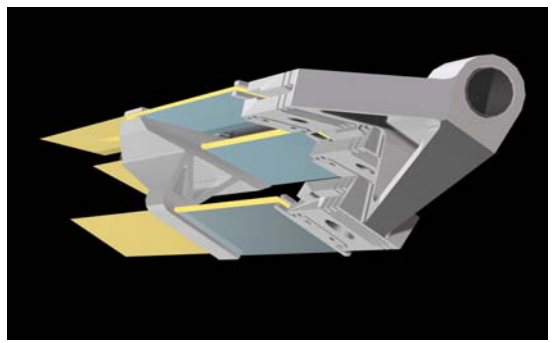
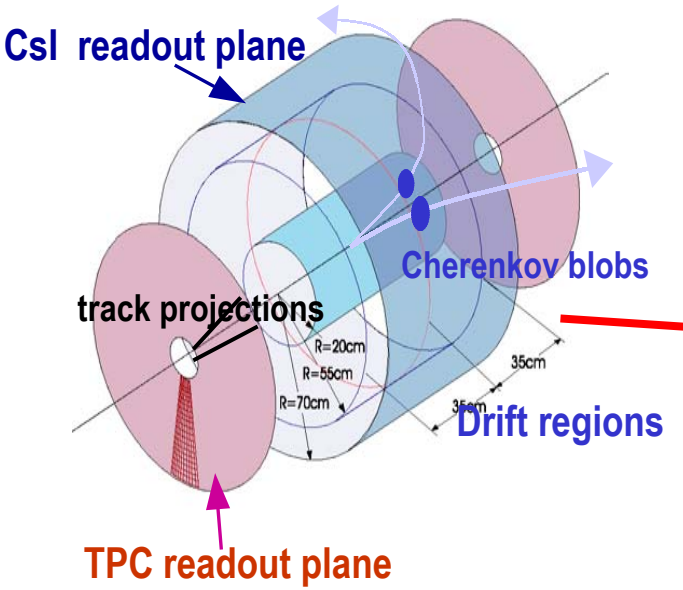
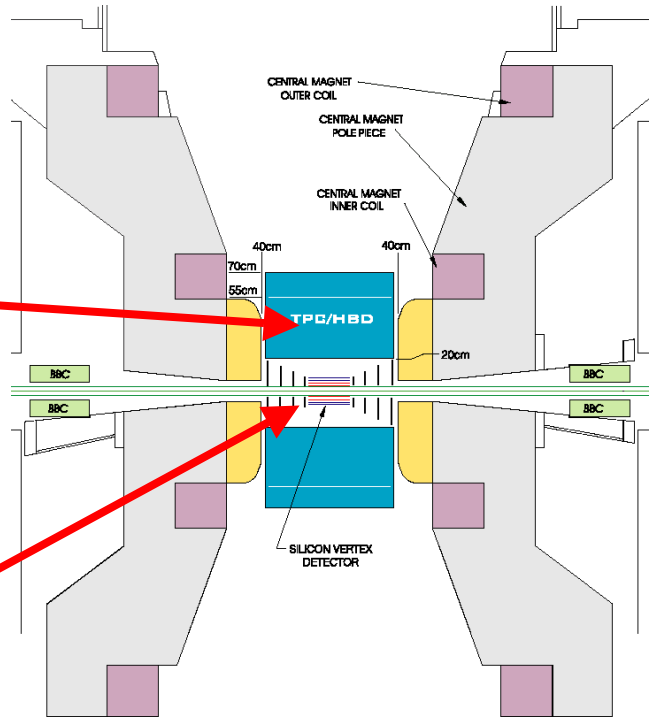
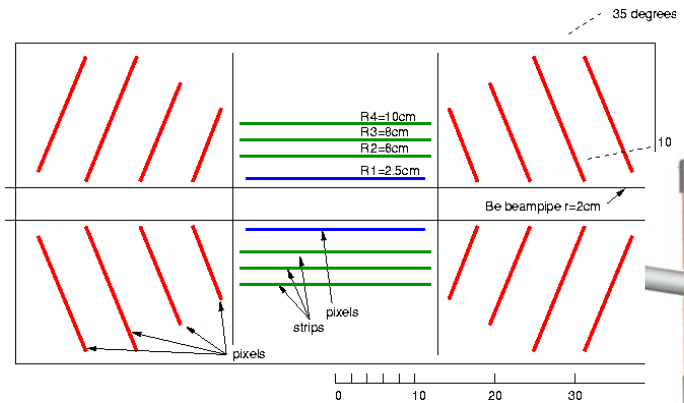


PHENIX Inner Detector upgrades

Dalitz Rejector/TPC tracker

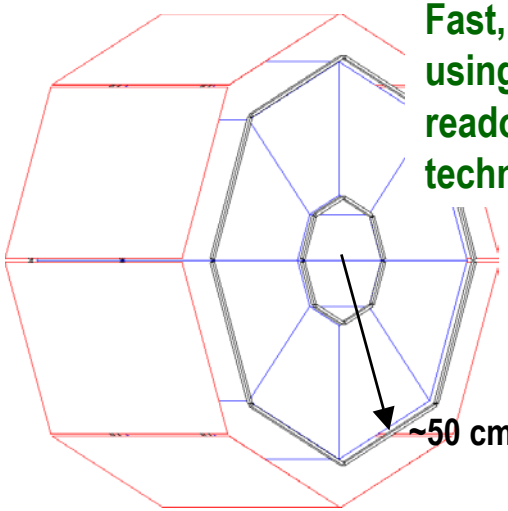




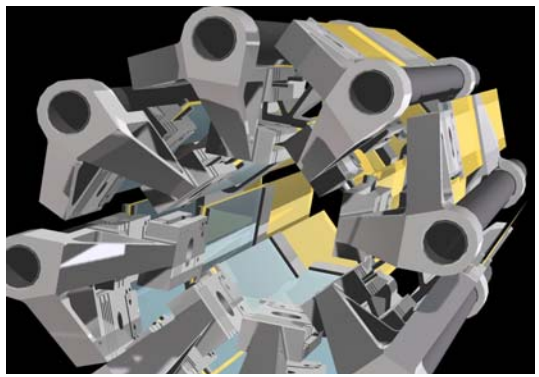


Si Vertex Detector

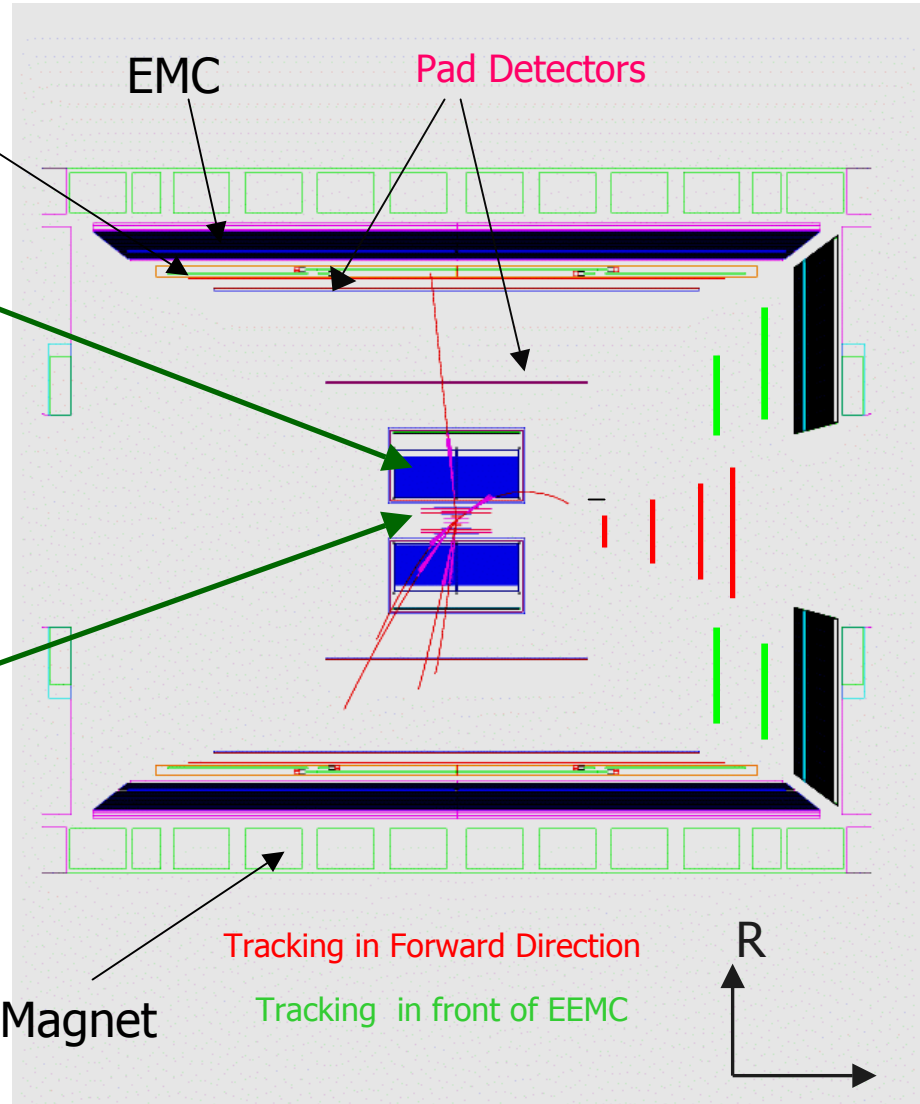
A Possible high-rate STAR configuration



Fast, compact TPC using GEM readout technology



Pixel detector using APS technology:
50 micron Si ladders held under tension.
C-fiber support outside active area.



Required detector upgrades center on the need for:

- *Precision inner tracking devices capable of directly observing charm and beauty decays (PHENIX and STAR)* [Si pixel detectors]
- *Fast, compact, high-resolution Time Projection Chambers (PHENIX and STAR)* [Micropattern readout: GEM]
- *"Hadron blind" tracking for efficient rejection of Dalitz and conversion electron pairs (PHENIX)* [GEM+CsI photocathode]
- *Extended range of particle I.d. (PHENIX* [Aerogel] *and STAR* [TOF with Multigap Resistive Plate technology]*)*
- *Improved data acquisition and trigger techniques to handle very large data volumes at high rates (PHENIX and STAR)* [More intelligence at the front-end]

RHIC Detector Advisory Committee

Inaugural meeting: BNL Dec. 20-21, 2002
Physics goals and R&D proposals for detector upgrades

Peter Braun-Munzinger (GSI, Darmstadt) [Chair], **Russell Betts** (U. Illinois, Chicago)
Don Geesaman (Argonne Nat. Lab.), **Carl Haber** (Lawrence Berkeley Nat. Lab.)
Berndt Mueller (Duke Univ.), **Rick Van Berg** (Univ. Pennsylvania), **Jerry Va'vra** (SLAC)

The Committee strongly endorsed the physics motivation for upgraded detectors, and concurred with the need for an immediate start on R&D to develop the necessary technology.

Proposed funding for detector R&D:

	FY 2003	FY 2004	FY 2005
BNL Request	**$1M**	**$2M**	**$2M**
PHENIX proposal	1.13M	1.46M	1.0M
STAR proposal	0.8M	1.7M	1.7M

Detector Advisory Committee Report

www.bnl.gov/physics/rhic_DAC.htm

The Report provides BNL with solid guidance for making funding decisions

R&D Projects recommended for support in FY 03

PHENIX Silicon Tracker	BNL, Stony Brook
PHENIX Hadron Blind Detector	Weizmann Inst.
PHENIX/STAR TPC (GEM)	BNL, Yale
STAR Electronics Upgrade	LBNL
STAR MRPC TOF	Rice Univ.
STAR Active Pixel Sensor	LBNL
STAR Data Acquisition	BNL

Detector Upgrade Projects

The Detector R&D program is expected to lead to a series of upgrades, evolving toward "RHIC II"

- Some of these upgrades can be achieved within the RHIC base
  (e.g. STAR FPD, PHENIX Aerogel [with Japan], PHENIX HBD)

- Two MIE projects are being considered for proposed starts in FY2005:
  PHENIX Si Tracker [with Japan]
  STAR Time of Flight [with China]

- Other projects are R&D-driven, and may be proposed for construction later.
  Some will have to be considered in the context of a future RHIC II project

BNL intends to move these detector upgrades forward on the basis of:

- Scientific priorities for RHIC
- Technical readiness
- Readiness of a viable funding and management plan

Summary

- R&D initiatives have been developed by PHENIX and STAR in response to physics requirements.

- These initiatives are now tightly integrated into the plans for each of these collaborations.

- The corresponding upgrades are of critical importance for continued success of the RHIC scientific program.